



Product: FORGINGS & BARS FOR PRESSURE CONTAINING PARTS of OFE for API-6A & API-16C

Revisions Record:

Rev 08: 24/03/15: Edition numbers for reference standards added. Cl 2 – Edition added, Temperature rating 'R' deleted, Cl 6 – Impact test modified, Cl 8 – Personnel qualification added, calibration modified, exception on test method in MPI added, term '... finished component' removed, Cl 11 – modified

Rev:09 : Dt: 20/10/2015 Cl.1, 2, 3, 5.0, 6.0, 8.0, 11.0 modified.

Rev 10: Dt: 22/12/2015 Cl 1, 2, 3, 4, 5, 6, 8, 10, 11 & 12 modified.

Rev 11: Dt: 19/08/2016 Cl 2 (100K Added), 5 (Table 2 modified) & 6 (Table 3 & 4 modified), Cl 8 modified to include definitions for relevant, linear and rounded indications.

Rev 12 Dt: 07/02/2017: Cl 1 changed to indicate the use of latest revisions of referred codes, standards, specifications, drawings, procedures, etc; Cl 5 revised to include HT Furnace calibration procedure; Cl 1, 2, 3, 4, 5, 6, 8, 10 & 11 revised to bring better clarity.

Rev 13 Dt: 04/05/2019 – Cl 2, 3, 5, 6 & 8 modified as per API 6A 21st Ed.

1. MATERIAL SPECIFICATIONS

All the codes, standards, specifications, drawings & procedures, etc., referred in this TDC shall be of latest revision as on the date of Enquiry/Purchase Order, whichever is earlier, unless specified otherwise.

Carbon Steel(CS)	:	AISI 1040
Alloy Steel(AS)	:	AISI 4130 & AISI 4140
Martensitic SS	:	AISI 410
Precipitation Hardened SS	:	ASTM A564 Type 630 (17-4 PH) Condition: H1150D
Additional Requirements	:	As listed below (Supplementary to above material specifications/standards)
Size and Quantity	:	As per Purchase order & Drawing.

2. APPLICATION

Pressure containing parts of oil field equipment meeting API-6A 21st Ed 2018 and API- 16C 2nd Ed 2015 Addendum 1 Errata 4, National Oil Well Spec MS 204, 382, 383, 384, 385, 386, 388 & 389, NACE Standard MR-0175 with

Product specification level (PSL) : API-6A: 1, 2, 3, 3G & 4; API-16C: 3, 3G & 4

Temperature rating: API-6A : P, S, T, U, V, X & Y

API-16C : A, B, U, X & Y

Material Class & Service : As per applicable drawing.

Material property designation : 60K, 75K , 100K & 105K

3. CHEMICAL COMPOSITION & PROCESS

Steel shall be of Fully killed and fine grained with Pressure vessel quality using any one of the following:

Melting process:

1) Electric furnace or Basic oxygen process or Induction melting followed by any one of the secondary steel cleaning processes such as vacuum degassing or vacuum processing, Argon Stirred Degassing, Argon Oxygen Decarburisation (AOD), Electroslag Remelting (ESR), Vacuum Arc Remelting (VAR), Ladle refining.

2) Vacuum induction melting.

3) *Melting practice used for PSL 4 material shall be documented by the manufacturer and reported in MTC.*

Ladle and product analysis, *on a heat basis*, in weight percentage per heat shall be as per Table 1:

Table 1. Chemical Requirements

Elements	Chemistry for various Material Specifications				
	AISI 1040	AISI 4130	AISI 4140	AISI 410	ASTM A564 Type 630
C	0.37-0.45	0.27-0.35	0.37-0.45	0.07-0.15	0.07 max
Mn	0.60-1.00	0.40-0.80	0.60-1.00	0.50-0.90	1.00 max
Si	0.15-0.45	0.15-0.45	0.15-0.45	0.15-0.50	1.00 max
P	For PSL 1 & 2 - Phosphorous and Sulphur: 0.04% <i>max.</i> each. For PSL 3 & 3G - Phosphorous and Sulphur: 0.025% <i>max.</i> each. For PSL 4 - Phosphorous: 0.015% <i>max.</i> & Sulphur: 0.010% <i>max.</i>				0.035 max
S					0.030 max
Ni*	0.50 max	0.50 max.	0.50 max.	1.00 max.	3.00-5.00
Cr*	0.50 max	0.80-1.30	0.80-1.30	11.5-13.5	15.0-17.5
Mo*	0.20 max	0.15-0.45	0.15-0.35	0.20 max.	---
V*	0.10 max.	0.30 max.	0.10 max.	0.10 max	---
Cu*	0.40 max.	---	---	---	3.00-5.00
Cb+Ta*	---	---	---	---	0.15-0.45
Fe	Remainder				

Notes to Table 1:

- *The total of these elements shall not exceed 1% for AISI 1040.
- Tolerance for above chemistry shall be as per the applicable material specifications/ *industry* standards.

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1. Material to be Ultrasonic tested (UT) as per standard in Cl.8.0 before forging to ensure freedom from defect, if UT is not possible at final stage. Wherever ingots are used, ingot shall be forged to an intermediate billet/bloom & UT tested before forging to final size & shape.
2. **Hot forging:** Forging shall be ensured for uniform wrought structure & strength with reduction ratio in area: 3:1 min. from ingot to finished forging, close to final size and shape. Grain flow lines parallel to axial length of forging. A forging plan shall be prepared & used indicating stages of forging and reduction ratio at each stage and the final reduction ratio shall be prepared for each type & size of forging.

4. DIMENSIONS AND TOLERANCES

Dimensions & their tolerances shall be as per applicable drawings. For untoleranced dimensions: CS & AS: as per SA 29; SS: as per SA 484.

5. HEAT TREATMENT(HT)

- a) Equipment/Furnace used for heat treatment to be qualified as per SIP:OF:01 (contains *heat treatment* requirements of Annexure M of API Spec 6A- 2nd Ed).
- b) Items to be Normalised, Quenched & Tempered, or to be Solution annealed & hardened as per table below together with Qualification Test Coupons (QTC).
- c) *In no case shall the QTC be processed using a melting practice(s) cleaner than that of the material it qualifies. The QTC shall be heat-treated in the same heat-treat furnace and same quench tank as the production parts that it qualifies.*
- d) Equivalent Round (ER) (determined as below) of QTC to be equal to or greater than the *dimensions* of the part it qualifies.
 - i. ER need not be > 63 mm (2.5") for PSL 1 & 2 parts.
 - ii. ER need not be > 125 mm (5") for PSL 3, 3G parts (except for bodies).
 - iii. *For PSL 3 & 3G, for bodies that require a yield strength of 75K or greater and where the part's weight during heat treatment is > 454 kg (1000 lb), the QTC ER shall be the same or greater than the part it qualifies but, is not required to exceed 250 mm (10 in.).*
 - iv. *For PSL 4, a prolongation or production part shall only be used. The testing shall use a prolongation or production part for each heat-treat lot. Individual prolongations or production parts corresponding to each quench shall be used for multiple quench batches from the same furnace load.*
- e) Determination of ER (applicable to PSL 1, 2, 3 & 3G): based on actual part size & shape in "as heat treated condition":

I) Standard Shapes:

- a) Round: ER = Diameter
- b) Hexagon: ER = 1.1 x Thickness
- c) Square: ER = 1.25 x Thickness
- d) Rectangle/Plate : ER =1.5xSmallest thickness
- e) Hollow shapes: ER = 2xWall thickness

II) Complex shapes: valve body, etc.:

1. Internal & external as forged surface within 12.5 mm. Of finished surface: ER = 1.25xT.
2. Surface not within 12.5mm as above: ER = 2xT. (T = max.thickness of Flange for flanged component / Body thickness for flange less component).

f) Heat sink for PSL 4:

Temperature levels for PSL 4 to be determined using a heat sink made of same alloy type as the part. ER (determined as above) of the heat sink to be $\geq$ largest ER of any single part in a HT load. A production part may serve as heat sink provided all requirements of this section are met. The temperature sensing tip of the thermocouple shall be within the part or heat sink and shall be no closer than one inch to any external or internal surface.

- g) Temperature of quench media (water/water based – polymer) at Start of quenching *shall not exceed 38°C (100°F)*. In case of oil, start temperature to be > 40°C.
- h) For bath-type quenching, the temperature of the water or quench media shall not exceed *49°C (120°F) at any time during the quench cycle.*

HT temperatures as below (Table 2): Tempering temperature range, wherever not provided, to be appropriately chosen to get required Mechanical properties meeting the minimum specified temperature in Table 2.

Table 2. Heat Treatment Requirements

Material	Heat Treatment Type	Temperature (°C)	Soaking Time (minutes/inch of max. thk)	Cooling medium of forging
AISI 1040 60K	Normalise	885-910	30	Air cool
	Quenching	830-870	30	Quenching in water or oil or polymer



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	Tempering	530(min)	60 (Min 60)	Air cool
AISI 4130 60K & 75K	Normalise	885-925	30	Air cool
	Quenching	830-870	30	Quench in oil or water polymer
	Tempering	635(min)	60 (Min 60)	Air cool
AISI 4140 60K,75K, 100K & 105K	Normalise	860-910	30	Air cool
	Quenching	820-870	30	Quenching in water or oil or polymer
	60K, 75K: Tempering	664(min)	60 (Min 60)	Air cool
	100K, 105K: Tempering	552(min)	60 (Min 60)	Air cool
AISI 410 60K & 75K	Quenching	955-1010	30	Quenching in air, water , oil or polymer
	I Tempering	663(min)	60	Air cool
	II Tempering	621(min)	60	Air cool
	Second tempering temperature shall be less than the first tempering temperature			
ASTM A 564 Type 630 (17-4 PH) Cond: H1150D 105K	Solution anneal	1038 ± 14	15	Air/liquid cool to < 320C
	Furnace must be at 1038 ± 140C before loading the parts. This steel to be heated rapidly through 843-954 deg C			
	1 st Hardening	621±8	Total 240 mts (for any thick)	Air cool to < 320C
	2 nd Hardening	621±8	Total 240 mts (for any thick)	Air cool to < 320C

6. MECHANICAL TESTS:

- Extent of test: One specimen for each size/heat/HT batch from acceptable Qualification Test Coupon (QTC) forged in similar manner.
- The test specimen to be removed from test coupon as follows:
 - Solid coupon: from centre core of the coupon with the longitudinal centreline axis of specimen wholly within the centre core ¼ thickness envelope.
 - Hollow coupon: Longitudinal centreline of specimen to be within 1/8" of the mid thickness of the thickest section.
 - Tensile specimen gauge length and Charpy V-notch root to be at least ¼ of the thickness of coupon from each end of the coupon.
 - When actual production part is used as coupon, specimen to be taken from thickest section of part.
 - For PSL 4, a prolongation or production part shall be used. The testing shall use a prolongation or production part for each heat-treat lot. Individual prolongations or production parts corresponding to each quench shall be used for multiple quench batches from the same furnace load.*
- Tensile Testing** shall be performed at a temperature between 4 °C and 50 °C as per ASTM A370 and acceptance as per Table 3:

Table 3. Room Temperature tensile testing acceptance

Material	Material Designation	Yield Strength in PSI (min)	Tensile Strength in PSI (min)	% Elongation on 2" GL (min)	% Reduction in area (min)
AISI 1040	60K	60,000	85,000	18	35
AISI 4130, AISI 4140, AISI 410	60K	60,000	85,000	18	35
AISI 4130, AISI 4140, AISI 410	75K	75,000	95,000	17	35
AISI 4140	100K	100,000	125,000	16	50
AISI 4140	105K	105,000	125,000	16	50
ASTM A564 Type:630	105K	105,000	125,000	16	50

All yield strengths shall be determined using 0.2% offset method of ASTM A370.

Retesting: If the results of the tensile test(s) do not satisfy the above requirements, two additional tests on two additional test specimens (removed from the same QTC with no additional heat treatment) to be performed in an effort to qualify the material. The results of each of these tests shall satisfy the applicable requirements.

- Tensile Tests at Elevated temperatures for materials of X & Y temperature ratings (Refer applicable drawing):**
The elevated-temperature tensile test(s) shall be performed on specimens removed from the same QTC used for room-temperature tensile testing. At least one elevated temperature tensile test shall be performed each at 180°C for X

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temperature rating and 345°C for Y temperature rating, using the methods of ASTM E21 and shall meet the requirements of below Table 4.

Table 4. Elevated Temperature Yield & Tensile Strengths

Sl No	Material	Material Designation	Min.YS for X Temp rating (PSI)	Min.YS for Y Temp rating (PSI)	Min.TS for X Temp rating (PSI)	Min.TS for Y Temp rating (PSI)
1	AISI 1040	60K	51,000	45,000	72,250	63,750
2	AISI 4130, 4140 & 410	60K	51,000	45,000	72,250	63,750
3	AISI 4130, 4140 & 410	75K	63,750	56,250	80,750	71,250
4	AISI 4140	100K	85,000	75,000	1,06,250	93,750
5	AISI 4140	105K	89,250	78,750	1,06,250	93,750
6	ASTM A564 Type:630	105K	89,250	78,750	1,06,250	93,750

All yield strengths shall be determined using 0.2% offset method of ASTM A370.

Retesting: If results of test do not conform to requirement, two additional tests on two additional test specimens (removed from the same QTC with no additional heat treatment) to be performed in an effort to qualify the material. Results of each of the tests shall satisfy the above requirements.

- e) **Hardness tests** as per ASTM E10 or E18: Hardness acceptance values as given below:
For material designation 60K: 174- 235 HBW; For 75K: 197-235 HBW; For 100K: 269-311 HBW; For 105K: 255-311 HBW;
Location of hardness check shall be as per drg. No. 4-V-4000-08373.Extent of Test: On QTC Minimum 2 tests.
On actual production forgings/bars: As below
- PSL 1: upto 5000 PSI working pressure: 2 nos per heat / HT batch.
above 5000 PSI working pressure : 100 %.
 - PSL 2, 3, 3G & 4: 100%
 - PSL 1 to 4 All Tubing Hangers : 100%
- f) **Impact (Charpy V-notch) test as per ASTM A370**: From QTC for PSL 1, 2, 3, 3G & 4:
Min. 3 specimens *shall be* tested at -29°C.

Acceptance: Min. average: 20 Joules *for specimens taken in Transverse Direction and 27 Joules for specimens taken in Longitudinal Direction*. Individual min.: 2/3 of min average. Only one of the three values may go below the minimum average.

Retesting: If a test fails, then retest 3 additional specimens (from *required* location within same QTC with no additional heat treatment), each of which to exhibit impact value $\geq$ min. specified average value.

Note: API-6A & 16C: Sub-size specimens shall not be used for PSL 4.

7. WORKMANSHIP AND FINISH

Items to be machined wherever required. To be examined visually & to be free from scales & defects like laps, seams, folds, cracks, etc. Forgings to be clean, trimmed of flash & shot blasted to remove scales after HT.

8. NON-DESTRUCTIVE TESTING

NDE personnel qualification: As per BS EN ISO 9712 /ASNT SNT-TC-1A.

a) Volumetric NDE:

- 1) PSL 1&2 of API-6A: 100% Ultrasonic test(UT) on bars of Dia $\geq$ 50mm & forgings of thickness $\geq$ 10mm as per ASTM A388.
Acceptance: Item shall be unacceptable if examination result shows one or more reflectors which produce indications accompanied by complete loss of back reflection.
- 2) PSL 3, 3G & 4 of API-6A & API-16C parts: 100% UT on all rolled/forged bars and forgings as per flat bottomed hole procedure of ASTM A388 and ASTM E 428.
Immersion method shall not be used.

Calibration (including Stems for API 6A applications): Distance amplitude curve (DAC) to be based on 1.6 mm flat bottomed hole for metal thickness upto 38 mm; 3.2mm flat bottomed hole for metal thicknesses from 38 mm to 150mm and 6.4mm flat bottomed hole for thickness exceeding 150mm.



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Acceptance:

- a) No single indications exceeding reference DAC.
- b) No multiple indication exceeding 50% of the reference DAC. Multiple indications are defined as two or more indications each > 50% of the reference DAC within 13 mm of each other in any direction.
- c) For PSL 4, in addition to above a) & b) - no continuous cluster of indications on the same plane, regardless of amplitude, shall be found over an area twice the diameter of the search unit.

In case of stems for API 16C applications, additionally, each stem to be Ultrasonic Tested from outer diameter & ends by straight beam technique. Stems which can not be examined axially using straight beam technique to be examined using angle beam technique with a beam directed along the axis in both directions. Calibration shall be done with DAC based on 3.2mm flat bottom hole for straight beam technique and 1.6mm side drilled hole, 25mm deep for angle beam technique.

Acceptance criteria shall be as per PSL 3, 3G & 4 above.

b) Surface NDE:

- a) Relevant indication: Surface-rupture NDE indication with major dimensions greater than 1.6 mm (1/16 in).
- b) Linear indication: Surface NDE indication whose length is equal to or greater than three times its width.
- c) Rounded indication: Surface NDE indication whose length is less than three times its width.
- d) CS, AS: 100% MPI as per ASTM E 709 for PSL 1 & 2 and 100% Wet MPI as per ASTM E709 for PSL 3, 3G & 4. Prod method is not permitted.

Acceptance:

- 1) All PSL: No relevant indication permitted on any pressure contact sealing surface.
- 2) For PSL 1: Linear indications like cracks, folds & other injurious defects are unacceptable.
- 3) For PSL 2, 3, 3G & 4: Following shall be complied with in addition to PSL 1 requirement.
 - ☐ no relevant indication with a major dimension equal to or greater than 5 mm (3/16 in);
 - ☐ no more than ten relevant indications in any continuous 40 cm² (6 in.²) area;
 - ☐ four or more relevant indications in a line separated by less than 1.6 mm (1/16 in) (edge to edge) are unacceptable.

- e) LPI for SS: 100% as per ASTM E165.

Acceptance:

- 1) All PSL: No relevant indication permitted on any pressure contact sealing surface.
- 2) For PSL 1: No linear indications acceptable.
- 3) For PSL 2, 3, 3G & 4: Following shall be complied with in addition to PSL 1 requirement.
 - ☐ no relevant linear indication;
 - ☐ no relevant rounded indication with a major dimension equal to or greater than 5 mm (3/16 in);
 - ☐ no more than ten relevant rounded indications in any continuous 40 cm² (6 in.²) area;
 - ☐ four or more relevant rounded indications in a line separated by less than 1.6 mm (1/16 in) (edge to edge) are unacceptable.

9. REPAIR

Repairs by fusion welding are prohibited. Surface defects can be removed by mechanical means and defective areas smoothly dressed up with the adjacent surface. Minimum thickness after repair to meet drawing / Specification.

10. MARKING AND PACKING

Details of stamping on each item with low stress stamps and border by paint:

(1) Heat number, (2) Material Specification & grade, (3) Size, Maker's emblem/code, (4) Identification details as per drawing. Items to be coated with a layer of rust preventive coating before despatch. Forgings to be properly packed and despatched to avoid damage during transit.

11. INSPECTION AND CERTIFICATION

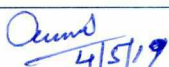
All tests specified to be carried out by forger and test results to be furnished in the test certificate of type 3.1 or 3.2 as per BS EN 10204 and shall contain the following information in English language only:

1. Purchase Order No.(BHEL), TDC No & its revision no, Test certificate no & date, Part name
2. Material Specification & Grade with year of code, Heat Number, Drawing No., Quantity & Size
3. Applicable API Specification, PSL No, Temperature Rating, Material Class, Material Property Designation
4. Melting process (for PSL 4 only)
5. Forging process, Chemistry with incidental elements- Heat wise ladle & Product analysis.
6. Heat treatment details of the material and test bars like – actual soaking temperature, soaking time, rate of heating & cooling, cooling medium etc. For PSL 4, actual recorded HT chart shall be submitted).
7. Mechanical test results: Room temperature Tensile Strength, Yield Strength (0.2% offset), %Elongation, %Reduction in Area, Impact, Hardness; Elevated temperature tensile & yield (0.2% offset) strength values, as applicable.
8. NDE Personnel qualification records, NDE test results with reference & acceptance standard (surface, volumetric).
9. Repair details if any, Certified copy of TC for starting material.
10. Dimensional reports (for PSL 3, 3G & 4 only).

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12. AUDIT CHECKS AT BHEL

BHEL reserves the right to carry out audit checks for chemistry, HT condition, mechanical test and NDT on representative test bars or job. Items found defective during check or subsequent processing at BHEL will be rejected.

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Venkanna Rupani	G. Panneer Selvam	R. Elayaraja	R. Ananthakrishnan	Amit Roy
Dy. Manager /QA	DGM/QA	Manager/ Valves/Engg	AGM/Valves/ Purchase	AGM/QA&BE
Prepared By	Reviewed By			Approved By